LOCATING SYSTEM FOR MOBILE STATIONS

This invention relates to a system for estimating the locations of mobile stations in a cellular radio system. For example, the mobile stations could be mobile telephones in a cellular telephone system.

Figure 1 is a simplified schematic diagram of the radio coverage in an area of a cellular radio network. A number of base-stations 1 to 9 are distributed over the area. Each base-station has one or more base-station transceivers which can transmit and receive radio signals to and from mobile stations. Each base-station transceiver transmits to and receives from a limited area, which represents the cell associated with that base-station transceiver. Figure 1 shows cells 10-19. When a mobile station is in a cell it communicates with the base-station transceiver associated with that cell. As shown in Figure 1, the cells vary in size and shape depending on factors such as the directionality, transmit power and receive sensitivity of the base-station transceiver, and the topography around the base-station. For example, cells 10 and 11 are relatively large and surround their respective base-stations 1 and 2 generally evenly - these represent typical cells in a rural area; cells 12 and 13 are elongate and extend in opposite directions along a main road 22 from a single base-station 3; cells 14-18 are very small - these are typical cells in an urban area.

In a typical cellular radio system the transmissions of each mobile station must be synchronised with the timing of its current base-station. As the mobile moves closer to the base-station its transmissions take less time to reach the base-station; therefore, to maintain synchronisation, it delays its transmissions increasingly (under command from the base-station) as it approaches the base-station. For example, in the GSM cellular telephone system once a connection has been established between a base-station and a mobile station the base-station continually measures the time offset between its own clock and the timing of the signals received from the mobile station. Based on these measurements it calculates a timing advance from 0

to 233 μs, coded as a number from 0 to 63 which it transmits regularly to the mobile station. The base-station therefore knows the timing advances (TAs) for all the active mobile stations in its cells.

Since the timing advance is largely determined by the speed of radio propagation (which is known) and the distance of the mobile from the base-station it might be expected that knowledge of the TAs could allow the system to estimate the geographical locations of the mobile stations. For example, where several cells overlap it might be expected that triangulation using the cells' TAs could permit estimation of a mobile's position. However, such schemes have met with many practical difficulties (such as coping with time delays caused by reflected signals) which have made the schemes too complex for widespread implementation.

There is thus a need for a more easily implemented system to allow the geographical location of a mobile station to be determined.

According to one aspect of the present invention there is provided a method for estimating the location of a mobile unit in a cellular radio system, comprising: identifying a cell of the system in which the mobile unit is located; estimating the distance of the mobile unit from the base-station of the cell; determining the location of the base-station; determining bearing information associated with the cell, the bearing information defining a direction; and calculating a location offset from the base-station by the said distance in the said direction to estimate the location of the mobile unit.

In one preferred arrangement the said cell is a cell of a first type and the method comprises the step of, if the mobile station is located in a cell of a second type, estimating the location of the mobile unit to be the location of the base-station of that cell of the second type. The first type of cell may be a cell of generally elongate coverage area. The second type of cell may be a cell of generally non-elongate coverage area.

Preferably the method comprises determining whether the cell in which the mobile unit is located is of the first type or the second type. This may be done on the basis of a stored indication of the type of each cell.

The bearing information is preferably independent of the location of the mobile unit within the cell. The bearing information preferably indicates a direction in which the coverage area of the cell is elongate.

The distance of the mobile unit from the base-station is suitably estimated by means of synchronisation information of the cellular radio system. One example of such synchronisation information is timing advance information. Thus, the synchronisation information suitably represents a timing offset between the mobile station and the base-station.

Once the location has been estimated further action such as processing or sending of messages bay be performed to utilise the location information. For example, a message may be sent to the mobile station in dependence on the estimated location. Such a message suitably indicates the estimated location and/or indicates the result of processing based on the estimated location. Such a message may be sent by, for instance, a voice format or a data format such as a text message format. One example of such processing is the calculation of a route between a certain location and the estimated location of the mobile station. That certain location may be received from the mobile itself, for example if the user of the mobile has initiated the calculation of a route to that location.

The estimation of the mobile's location is suitably initiated by a message from the mobile requesting estimation of its location and/or by the elapse of a predetermined time from an event such as the last estimation of the mobile's location.

According to a second aspect of the present invention there is provided a locating unit for estimating the location of a mobile unit in a cellular radio system, the unit being connected to the cellular radio system for reception of information identifying a cell of the system in which the mobile unit is located and information indicative of the distance of the mobile unit from the base-station of the cell, the locating unit comprising: data storage means storing the location of the base-station and bearing information associated with the cell, the bearing information defining a direction; and location calculating means for calculating a location offset from the base-station by the said distance in the said direction as an estimate of the location of the mobile unit.

The data storage means suitably stores cell type information associated with the cell, the cell type information indicating whether the bearing information is to be used in estimating the location of a mobile unit in the cell.

The unit may also comprise logic means for, in dependence on he cell type information, causing the location calculating means either: if the said cell is a cell of a first type, to calculate a location offset from the base-station by the said distance in the said direction as an estimate of the location of the mobile unit; or if the said cell is a cell of a second type, to take the location of the base-station as an estimate of the location of the mobile unit. The unit may also comprise messaging means for generating a message in dependence on the estimated location for transmission to the mobile unit.

According to a third aspect of the present invention there is provided a locating unit for reporting the location of a mobile unit in a cellular radio system, the unit being connected to the cellular radio system for reception of information identifying a cell of the system in which the mobile unit is located and information indicative of the distance of the mobile unit from the base-station of the cell, the locating unit comprising: data storage means storing descriptive information associated with one or more possible distances of a

mobile unit from the base-station of the cell; and location reporting means for generating a report on the location of the mobile unit based on the descriptive information that corresponds to the distance of the mobile unit from the base-station of the cell.

The descriptive information may suitably include place name information and/or road name information and/or distance information. The location reporting means preferably transmits the report to the mobile unit.

The location reporting means may comprise a wireless application protocol (WAP) server or a WTA server of WAP which has a secure connection to a WAP gateway. The location reporting means may comprise means for accepting a request for information on the location of the said mobile unit from a second mobile unit. The said request may be made by means of the wireless application protocol.

According to a fourth aspect of the present invention there is provided locating apparatus for reporting the location of a mobile unit in a mobile telecommunication system including positioning means for determining the geographic location of a mobile unit in response to a request including information identifying that mobile unit, the locating apparatus comprising: location request means for requesting the geographic location of a mobile station from the positioning means; geographic location translation means for receiving the geographic location of the mobile unit from the positioning means and translating the said geographic location into descriptive information; and location response means for generating a response message comprising the said descriptive information.

Suitably the locating apparatus may be capable of providing a content service to respond with the said descriptive information. That may be a wireless application protocol service. The said positioning means may be a mobile location centre.

According to a fifth aspect of the present invention there is provided a method for providing a report on the location of a first mobile station, the method comprising: a second mobile station transmitting a request for information on the location of the first mobile station; estimating the location of the first mobile station; generating a report on the location of the first mobile station; and transmitting that report to the second mobile station; wherein the request and/or the report are transmitted by means of the wireless application protocol. Suitably, the report may be generated by a wireless application protocol server. In addition to the WAP wireless session protocol the request and report may be transmitted using any content transfer protocol, for instance internet hypertext transfer protocol (HTTP).

In each aspect of the invention the mobile unit may, for example, be a radio telephone.

The present invention will now be described by way of example with reference to the accompanying drawings, in which:

figure 1 illustrates cell coverage in a cellular telephone system;

figure 2 shows a schematic diagram of a cellular telephone system;

figure 3 is a flow diagram of the procedure for locating a mobile station;

figure 4 is a schematic diagram of a the environment of a cellular telephone system;

figures 5 and 6 show schematic diagrams of architectures for implementing a locating system in a GSM network; and

figure 7 shows a signalling scheme for requesting information on the position of a mobile station.

The system of figure 2 includes a mobile locating unit (MLU) 30 connected to base-stations 1 to 9 of figure 1 via mobile service centres (MSCs) 31 to 34. The MLU has access to information from the base-stations and data stored in a coverage database 35a and uses them to estimate the geographic location

of mobile stations 36,37 (e.g. cellular telephone handsets) in the system. The basic principle used to locate the mobile stations is as follows. The database 35a stores, for each cell, the geographic location of that cell's base-station and an indication of, when a mobile station is in that cell, whether or not the mobile station's timing advance should be used to estimate the mobile station's location. For the cells for which timing advance is to be used to estimate mobile station location the database also stores bearing data, which indicates the compass bearing from the cell location that mobiles in that cell will be assumed to lie on. Then to estimate the location of a mobile station the MLU determines via the MSCs which cell the mobile is currently in. The MLU consults the information on that cell that is stored in the database 35a. If the database indicates that timing advance (and bearing data) should not be used to estimate the locations of mobiles in that cell then the MLU estimates the mobile station's location to be the location of the base-station associated with that cell. If the database indicates that timing advance (and bearing data) should be used for locating mobiles in that cell then the MLU obtains from the database the bearing data for that cell and obtains from the base-station associated with that cell the mobile station's timing delay. The timing advance is converted to a distance using the known speed of propagation of the radio signals, and the location of the mobile station is estimated as being at a position offset from the base-station by that distance in the direction defined by the bearing information.

The process is illustrated by the flow diagram in figure 3.

The indication of whether the timing delay / bearing data is to be used for any base-station could be stored separately from the bearing data itself, or a special value of the bearing data for a base-station (e.g. 400°) could be used to indicated that the timing delay / bearing data is not to be used for that base-station.

The process of estimating the mobile's location could be initiated by the sending of a message from the mobile to the MLU over the radio system.

The cells for which the database defines that the TA should be used in locating are elongate cells (such as cells 12 and 13 in figure 1), for which the corresponding bearing data defines the compass bearing along which the elongation of the cell extends from the associated base-station. The other cells are those for which the TA is not used in locating.

Therefore, referring to figure 1, if the mobile is in one of the cells 14 to 18 its location will be estimated to be the location of the respective base-station 5,8,9,7,6. Since these cells are small in area and centred on their respective base-station the estimate of location will be relatively accurate. If the mobile is in one of the cells 12,13 its location will be estimated using the TA to lie at a point along the major axis of the cell. Since these cells are narrow perpendicular to that axis the estimate of location will again be relatively accurate, subject to errors due to disproportionality of the TA with distance from the base-station caused by factors such as reflection of signals. If the mobile is in one of the cells 10,11,19 then its location will be approximated to be the location of the respective base-station 1,2,4. This is relatively inaccurate but since these are rural cells, in many networks a typical mobile will only rarely occupy such a cell. The present system therefore provides a greatly simplified method of locating mobiles, with relatively little loss in performance over much more complex systems.

The process of calculating an estimate of a mobile's location from its timing advance will now be described. Using a normal orthogonal geographical grid system the location of a base-station (e.g. base-station 3 in figure 1) can be indicated as co-ordinates x_b, y_b, where x_b is a northing and y_b is an easting. The bearing data for the relevant cell can be indicated as θ degrees from north and the mobiles' timing delay can be indicated as t seconds. Taking the speed of radio signals to be $v = 3 \times 10^8$ ms^{-1} the mobile's distance d from the base-station is estimated by:

$$d = v\,t$$

and the co-ordinates of the mobile's estimated location are x_m, y_m, where:

$$x_m = x_b + d \cos \theta$$
$$y_m = y_b + d \sin \theta$$

Once the location of the mobile station has been determined the MLU can transmit that information to the mobile station or another unit. Some convenient ways for this to be done are by text or voice messages over the radio system. For instance, in a GSM system text messages could be sent by SMS (short message service) or USSD (unstructured supplementary services data).

The MLU (or another unit having received the location information) could perform further processing based on the location information together, optionally, with other information such as information derived from a geographical database 35b. The geographical database could, for example, store the locations of geographical features such as towns and roads: one example of such a database is the Finnish Genimap system. Examples of the further processing that is possible are as follows:

1. The MLU could determine the location of the mobile relative to geographical features in the database and generate a message to report the location relative to those features, such as "you are in town X" or "you are between towns X and Y" or "you are 5km from town X on road Z".

2. If the MLU is capable of receiving messages from a user of the mobile (e.g. by the SMS system) the user could, by means of a message, request the MLU to use its database to perform a calculation and report the result by a message. For example, the user could request the MLU to suggest a route from the mobile's location to a specified location, or to calculate the distance from the mobile's location to a specified location. The MLU could also suggest a route from the mobile's current location to a present location such as the mobile user's home. The mobile user's home location could be determined by the MLU from information available from the radio network's billing centre or subscriber database. Using estimates of driving speeds and travel costs the MLU could report estimated journey times and costs for suggested routes.

3. The MLU could (e.g. following a request by the user) send messages periodically (e.g. every 15 minutes) to report the mobile's location.

Figure 4 illustrates a specific example of location estimations. Figure 4 shows the A616 road extending between the towns of Olvila and Kosula and covered by an elongate radio cell from a base-station 38. The base-station measures and calculates the timing advance for the mobile station and gets the value 21. This value 21 corresponds to a distance of 8km from the base-station 37 at Turpela. So the location of the mobile station is 12km (4km + 8km) from Olvila, and 13km (21km - 8km) from Kosula. By monitoring the mobile's location over time the direction of movement of the mobile along the road/cell can be determined.

If the user asks to know the distance to some far away place, for example Hauho, we need to compare the distance from Hauho to Olvila and from Hauho to Kosula. The shorter way (= Kosula - Hauho plus 12km) will be informed to the user and it will also be used for route assistance. The mobile station user could get a message "you are in Aavasaksa (A616), 12km from Olvila and 13km from Kosula, you have 583km to go to Hauho, Do you want route assistance?" To simplify the integration of the coverage database 35a with the geographic database 35b the locations of base-stations could be approximated to geographic locations already held in the geographic database. Alternatively, the two databases could use a common geographical grid system or the MLU could translate between different grid systems

used by the databases. In some cases supplementary locations could be added to the geographic database, also to assist in calculating routes and distances.

Another alternative avoids the need for the storage of bearing information. One of the databases could store a list of descriptive information to each or to a range of timing advances. Once the location of a mobile station had been determined a description of the mobile station's location based on that descriptive information could be reported to a user. In the example of figure 4, the table could hold the following information:

Timing Advance	Place	City 1	City 2	Road
0 to 7	Turpela	Olvila	Kosula	A616
8 to 16	Jankhala	Olvila	Kosula	A616
17 to 22	Aavasaksa	Olvila	Kosula	A616
23 to 35	Perala	Olvila	Kosula	A616
over 35	Kosula	Kosula	Kosula	A616

City 1 and city 2 are major places between which the mobile station's location lies.

Examples of descriptions based on this information that could be reported to a user at timing advance 10 are:

"You are in Jankhala on the A616"

or (by calculation of the distance corresponding to a certain timing advance and knowledge of the distance of the base station from city 1 and city 2):

"You are in Jankhala (A616) 9 kilometres from Olvila and 16 kilometres from Kosula".

For non-linear cells, or in general cells for which the distance of the mobile unit from the base station is not to be taken into account in generating a report of the mobile station's location, the corresponding table could hold merely a single set of location data describing, for example, the central point of the cell.

Figures 5 and 6 show some schematic architectures for implementing this system in a GSM cellular telephone network. Like reference numbers refer to like units in these

figures and figure 2. In figure 5 the MLU 30 is connected to the network via a messaging unit 39 that allows bi-directional SMS or USSD message traffic between the MLU 30 and mobile 36. In figure 6 there is also a messaging platform 41 that acts as a gateway between the messaging unit 39 and a network 40, such as the internet, via which the MLU 30 is connected to the cellular network.

It will be appreciated that the present invention is especially advantageous in connection with in-vehicle mobile cellular radio mobile units. The mobile unit could be a mobile telephone or another mobile communication unit. The cellular network could be a cellular telephone network.

The invention may also be implemented with the proposed GPRS (general packet radio service). The proposed GPRS standards define support for a short message service centre and the GPRS radio interface also makes use of calculated/measured timing advances. The high data rates (40-100kb/s) available through GPRS could allow for more convenient use of data-intensive functionality. For example, having estimated the location of a mobile station the MLU could transmit information to the mobile station to allow it to display a map of its surroundings. Of course, such a feature could be implemented, albeit less conveniently, in systems having lower data rates. In the GPRS system messages to or from the mobile unit and/or the MLU could be sent via the SGSN (serving GPRS support node) or the MSC (mobile switching centre).

Signal strength information may be used either instead of or in combination with the timing advance information to estimate the distance of the mobile from the base-station.

When a person makes a telephone call to a mobile telephone one of the first things that he often asks the user of the mobile station is the location of that user. It would be useful for there to be a procedure whereby this information could be exchanged automatically. Figure 7 illustrates a signalling scheme whereby one mobile station may request and receive information on the location of another mobile station. In connection with this signalling method the location of the latter mobile station may be determined in accordance with the procedures described above or in another way,

and could be in accordance with GSM 03.71. The unit requesting the location information may be a mobile station or another unit capable of the necessary signalling.

The signalling scheme illustrated in figure 7 involves a request by a mobile station MS1 (illustrated at 50) for information on the location of another mobile station MS2. MS1 is operable according to the WAP (wireless access protocol) and has a WAP user agent 51 and a WAP repository 52. Also illustrated in figure 7 are a WAP gateway 53, a WTA server 54 and a mobile network 55 in which the mobile station MS2 is operable. The WTA server has access to a location information server 56, and the mobile network includes an MLC (mobile location centre) 57 which could be in accordance with GSM 03.71. The mobile location centre 57 provides a service for determining the location of MS2, and preferably also stores the last known location of MS2. The location information server 56 includes a geographical database of verbal descriptions of locations, whereby a descriptive phrase may be generated in response to location information as provided from the location information server. The verbal descriptions may be supplemented or replaced by graphical pictures comprising a map. In that case the geographical database may include a map database performing mapping from location information to map extracts.

The operation of the signalling scheme of figure 7 is as follows. The WAP user agent 51 makes a request for the URL (uniform resource locator) of the location description service. The URL specifies a WAP deck to interface to the location information service. The user of MS1 inputs the identity of MS2, which can for example be the MSISDN of MS2. The WAP deck issues a request for a URL for the same location description service; this time the URL including the identity of MS2. MS1 sends the request to the WAP gateway 53, which forwards that request to the WTA server 54. The WTA server extracts the identity of MS2 from the URL.

Thereafter, the WTA server contacts a GMLC (gateway mobile location centre). The GMLC contacts the HLR of MS2 (not shown in figure 7) in order to determine which network and visitor MSC/VLR MS2 is currently operating in. The GMLC then requests the position of MS2 from the visitor MSC/VLR. The visitor MSC/VLR determines the location of MS2 and returns the result to the GMLC. The GMLC

returns the result to the WTA server. The result may, for instance be given in co-ordinate form or as the identity of the cell in which MS2 lies. The WTA then consults location information server 56 in order to establish a description of that location – for example a place name or a street name. The WTA server returns that description to the WAP gateway, which transfers it back to MS1 to answer the position request from MS1. MS1 then displays the information to its user. The response could be transferred to MS1 as a response to the URL request containing the identity of MS2 or by WAP push, as an unstructured message or by another means. The WAP deck for the location description service may be available in the WAP repository when its URL is first requested, therefore its downloading from the WTA server may not be necessary.

The WTA server and the location information server may be seen as logical services. This means that they may be distributed to physical nodes in a number of different ways. For example, the WTA server and the location information server can be within the GMLC node.

For reasons of confidentiality it is preferred that a list of entities that are permitted to be given location information on a mobile station such as MS2 is stored. Such a list may be stored at the respective HLR. Thus, when the WTA contacts the HLR of MS2 the HLR may check that MS1 is permitted to receive location information about MS2 and otherwise causes the request from MS1 to be rejected. A WAP interface could be provided to allow a user to alter his list. The list may be part of location profile information. For this and other security reasons it is preferred that the WAP application is located at the WAP server.

The WTA server could store a list correlating user names and phone numbers or other identities (e.g. MSISDN). Alternatively the WTA server could be capable of consulting such a list stored elsewhere, for example at a global name server or HLR.

The GMLC could store the last known locations of mobile stations so that it can return the last known location of a mobile station if the mobile station is out of coverage (e.g. in a building) or switched off. The MLC could alternatively obtain that information from the appropriate VLR.

The present invention may include any feature or combination of features disclosed herein either implicitly or explicitly or any generalisation thereof, irrespective of whether it relates to the presently claimed invention. In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.